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Memoirs of the Department of Agriculture in India

CEPHALEUROS VIRESCENS, KUNZE
THE 'RED RUST' OF TEA

BY

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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1. HISTORICAL.

THE comparative rarity of algæ which do serious damage to plants of any sort renders the few cases in which they do occur of considerable interest. Hitherto no entophytic or parasitic alga has been described which can be considered as a serious blight on a cultivated crop with the solitary exception of that with which the present paper deals.* In this instance, however, there is no doubt that the so-called 'Red Rust' of tea, caused by the alga *Cephaleuros virescens, Kunze,* is the most serious blight of cryptogamic origin to which this plant is subject in North-East India, and it is one whose seriousness is now being recognized by planters all over this part of the country. We have dealt with this blight from a practical point of view in two publications issued in 1901 and 1904 respectively, but hitherto no technical account has been published concerning our investigations.

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* E. J. Butler has recently, however, called attention to the serious damage being done by *Cephaleuros virescens,* as a stem blight, to mango trees in the Malda district of Bengal. See *Proceedings of the Board of Agriculture for India, 1906.*

The present paper is designed to fill this gap, and it forms a résumé of our observations and experiments from 1901 to the present year.

THE DISEASE IN ASSAM.

The result of the presence of this alga, as a blight of tea, began to attract local attention about 1880. It was then termed *white blight* because of the peculiarity that leaves on shoots invaded by it were noticed to become variegated, and in a few cases quite white. But the interest in the matter was purely local, and the noticeable damage was not serious enough for the opinion of any specialist to be obtained.

During 1889 samples of tea twigs attacked by disease in the Nowgong district, Assam, were submitted to King and Cunningham, and were determined by the latter as being attacked by *Cephaleuros virescens, Kunze.* Cunningham wrote a very interesting account of the subject,* but it was evidently looked upon as a curiosity, and the recommendation given to uproot and burn all affected plants can only be explained as a possible one on this supposition. His description of the manner of action of the disease is, however, extremely exact, and represents precisely the process which is now going on on very many tea shoots in almost all the tea districts in India.

Shortly after this time (in 1895) Dr. (now Sir George) Watt made a rapid but extremely productive tour through the tea districts of Assam, and found the disease caused by this algal parasite much more widespread than had previously been imagined. He noticed it, for example, over the whole of Nowgong (Assam), and with regard to its distribution he stated as follows :—

"I have no direct evidence that it occurs as a dangerous tea blight in any other locality than Assam, and even in Assam it is most erratic. I found it in two adjacent gardens in the Nazira section of Sibsagar, in half a dozen or more gardens within a compact section of Nowgong, and in two or three gardens in Tezpur. The Nazira gardens in question might be spoken of as suffering from defective drainage. The Nowgong hills probably give to the tract of country below them a considerably different climatic condition to what prevails above them (namely, in Sibsagar and Dibrugarh), but that difference can hardly be accepted as sufficient reason for the prevalence of the blight in Nowgong, nor for its absence from Dibrugarh and practically also in Sibsagar. The report of its occurrence in Dibrugarh is, I believe, due to a garden in that district being under the management of a Company that has its head-quarters in Nowgong. Certain letters, having been issued by the manager during inspection duty in Dibrugarh, gave the reputation of the blight being found in that district. But if excessive rainfall, high humidity, and even occasional inundation be viewed as circumstances likely to favour the appearance and distribution of this blight, it might naturally be looked for in North Lakhimpur and the gardens of the North Bank generally, but to the best of my knowledge it nowhere occurs until on descending the valley the latitude of Tezpur and Nowgong is reached. It is thus significant that this blight should be confined to the portion of the Assam Valley indicated. Whether or not it exists still lower down, for example in Gauhati, Mangaldai and Goalpara, I am unable to say, but the restricted nature of its present distribution is certainly highly significant."

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* Bark Blight caused by *Cephaleuros virescens,* Kunze. Scientific Memoirs by Medical officers of the Army in India, Part X, 1897.

Watt did not add to our knowledge of the disease itself, and in his report practically reproduced Cunningham's conclusions.

In this state our knowledge of the blight remained until, in 1901, owing to an extremely serious visitation of the disease in Nowgong (Assam) one of the authors (H. H. M.) was deputed to devote time to a special inquiry into its nature and the means for combating it. Since that time it has been under almost continuous observation.

THE ALGA CAUSING THE DISEASE.

*Cephaleuros virescens, Kunze,** which causes the serious disease with which we are dealing, belongs to a group of air-growing algæ whose classification and general systematic position has given rise to considerable difficulty. Originally arranged with fungi and lichens, their algal nature was only recognized by Agardh (*Systema algarum*, 1824), and his classification has been adhered to by all workers since his time. The group, in spite of a large amount of work being done, remained in hopeless confusion until 1891, when the relations of its members were very completely worked out by G. Karsten.†

He placed all the algæ "living in air, characterized by the possession of hæmatochrom, and formed of rapidly growing, more or less ramifying cellular threads, with or without a covering of hairs" in the family of *Chroolepidæ.* This family is subdivided into four genera—*Trentepohlia, Chroolepus, Phycopeltis,* and *Cephaleuros*—of which the last only has any special interest in the present connection. None of the members of the other genera are known to be definitely parasitic.

The genus *Cephaleuros* was characterized by Karsten as possessing (*a*) a cellular disk with one or several layers of cells, (*b*) cellular threads growing in the upper layers, terminating either in a point as hairs, or in a swollen cell into which a number of "neck" cells are inserted, each carrying a sporangium head,—the so-called 'haken-sporangia.' In one case the 'haken-sporangia' are borne on 'neck' cells arising from the side of the cellular hairs.

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* Some confusion has arisen as to the proper botanical name to use for this alga. *Cephaleuros virescens* was used by Kunze in 1829 for an alga he described from Guiana, but his description is hardly sufficiently detailed to be *quite* certain that we are dealing here with the same alga, and his type specimens have disappeared. On this account Karsten in 1891 gave it the new name *Cephaleuros mycoidea* and published an exact description. We cannot think that the reasons given by Karsten are sufficient to justify the abandonment of the older name, and accordingly retain it here. In doing so we have the support of Professor Delacroix of Paris.

† Untersuchungen über die Familie der Chroolepiden. Annales du Jardin botanique de Buitenzorg, Vol. X., 1891.

The genus thus described has now been shown to be, in several of its members, parasitic or at least entophytic on a number of plants, but in all cases of which an account has yet been published, other than the 'Red Rust' of tea, the leaf has been the point of attack. Thus, for instance, as long ago as 1877, Cunningham considered that his *Mycoidea parasitica*[*] (now known as *Cephaleuros virescens*) was distinctly entophytic on most leaves on which he examined it. These included mango, rhododendron, ferns, crotons, and tea leaves from the Kumaon hills. He described it as a "destructive blight on plants of *Camellia japonica.*" Since that time the entophytic character of the alga in the majority of the cases described by Cunningham has been doubted by Marshall Ward,[†] who stated that he had never seen the rhizoids from the alga breaking into the leaf. It is most probable that Ward was, in general, correct in his criticism and that though the growth of the algal patch may lead to the death of the portion of the leaf covered by the algal thallus, yet no actual penetration takes place in most of the cases examined at that time by Cunningham. This was made very clear by the subsequent investigations of Karsten (*l. c.*).

But though the original cases cited by Cunningham of leaf parasitism on the part of *Cephaleuros* were probably not true cases of this, yet he himself was able, a little later, to point out what was an undoubted case of penetration of the leaf on another plant by the same alga.[‡] It is one which can be commonly seen in the Botanical Gardens, Calcutta, where we ourselves have observed the appearance Cunningham describes on the leaves of *Cinnamomum iners, Reinw.* Here the leaves are completely pierced by the algal cells, and fertile fructifications appear both on the upper and under surfaces.

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[*] On *Mycoidea parasitica*, a new genus of parasitic algæ, by D. D. Cunningham, Trans. Linn. Soc., Vol. I. (2nd series), Botany, 1880.

[†] On the structure, development, and life history of a tropical epiphyllous lichen by H. Marshall Ward, Trans. Linn. Soc., Vol. II. (2nd series), Botany, 1883.

[‡] On an entophytic alga occurring in the leaves of *Limnanthemum indicum*, with notes on a peculiarly parasitic variety of *Mycoidea*. Scientific Memoirs of Medical Officers of the Army in India, Part III. (1887).

Since that time other similar cases of entophytism by algæ of the same genus have been pointed out by Karsten (*l. c.*). He described a species, *Cephaleuros parasiticus, Karsten,* distinctly entophytic on *Calathea metallica,* and also on *Pandanus* leaves, and another, *Cephaleuros minimus, Karsten,* which similarly attacks *Zizyphus jujuba,* and is very destructive to its foliage.

The form in which it attacks tea as a serious blight is, however, of a totally different character, and in this case the young, woody shoots, and not the leaves, are the seat of and are killed by the disease. It will be seen that if this occurs in any abundance over an extended area, the results will be exceedingly serious. As a matter of fact, it *does* occur over practically the whole of the plains districts of North-East India, though with a very varying severity, and there are very few tea estates on which careful examination at the proper season of the year would not reveal its presence. We have quoted Watt's description of its apparently restricted distribution in his time, but it seems most likely that his tour took him over the ground at a season when the alga was not fruiting on the stem and was hence invisible to a naked-eye observer, and not that it was at that time absent from the districts in which he did not detect it. At present, at any rate, there is no doubt of its existence, whenever the condition of the tea bushes is such as to favour its presence, in very serious proportion, in every district of the Assam Valley, in Cachar, in Sylhet, in Chittagong, in the Duars (Jalpaiguri), in the Darjeeling Terai and in the lower Darjeeling hill districts. It was the recognition of the widespread distribution of the blight in serious amount which led to the detailed investigations of the life history and habits of growth of the alga, with special reference to the conditions favourable to its development, reproduction and distribution, described in the present paper. Though the disease has been under almost continuous observations since 1901, the principal experimental work was done in Nowgong (Assam) in 1904.

II.

THE GENERAL EFFECT OF CEPHALEUROS VIRESCENS ON THE TEA PLANT.

Red Rust occurs on the tea bush, as already indicated, in two easily recognizable forms, distinguished by their situation respectively on the surface of the leaf and in the cortical tissues of the stem; the former is usually an epiphyllous development, and has been fully described by Cunningham, Marshall Ward, and Karsten (*l.c.*) as observed by them on various host plants. There can be no doubt that the alga found on the tea leaf corresponds in form, manner of vegetable growth and of reproduction with the one to which the name *Cephaleuros mycoidea* was supplied by Karsten, but for which that of *Cephaleuros virescens, Kunze,* has been retained by former observers.

This leaf form can be found in fructification on tea leaves in any estate at any time of the year. It has little direct agricultural importance, except as a source from which the more serious stem infection is derived. (See Plate III, Fig. 2.)

During the months December to March practically all the leaf-bearing tea in North-East India is pruned, the usual method being to cut off the previous year's growth, leaving from one to four inches of new wood. At this time the alga, in whatever quantity it may be present, can never be seen in fructification on the new wood thus left in pruning, though an occasional patch, irregular in shape, may be seen on the older wood of the plant. This condition of things remains unchanged until the end of March or April, when, generally after the first heavy rain of the season, in a district badly affected by the blight, the small remains of the previous year's wood not cut off in pruning, suddenly take on a red colour in isolated patches of quite irregular shape, the red colour being simply due to the appearance of multitudes of the fructifying cellular hairs, carrying the sporangia characteristic of this genus of algæ. This is usually the first sign of the disease which is apparent to a casual observer, though previously it might have been noticed that the new shoots which had grown from the pruned stems in such cases had shown a lack of vigour and a tendency to cease growing (technically 'to become *banjhi*') which ought not to be found at that season of the year. As a matter of fact, as we shall show later, there is every probability that the infection has taken place in the previous rainy season (July—October or November) and that the fructifications seen in April and May are really the last stage in the life history of the alga on a dying stem.

Following, or sometimes preceding, the appearance of the red fructifying patches of alga on the stem of the bushes, the leaves on many of the shoots which have become '*banjhi*' rapidly become chlorosed more or less completely. Hence the name '*white blight*' or '*leprosy*' formerly given to the disease. As a rule, the appearance of these chlorosed leaves is followed by the death of the shoot on which they occur, and it is comparatively rare that a shoot which bears algal patches in any quantity is able to recover. In case they do so, the signs remain on the stem as a patch up to about three-quarters of an inch in diameter, with several vertical cracks, and surrounded by a black edge, the appearance of the whole being very characteristic. (See Plate I.)

Though the actual fructifying of the alga is by far the most general from April to June, yet from this time to the end of the year shoots may be found to bear patches covered with fruiting filaments which are quite fertile, and their presence has the usual effect,—either the death of the shoot or its absolute refusal to grow.

The appearance we have just described occurs principally on stems during their second year of growth, that is to say, on such stems as have been produced in the previous season. But similar patches may and do occur on the older wood of the bushes, and even sometimes on the main stem. Under these circumstances the alga seems usually unable to produce the same serious effect, and the shoots do not die beyond the algal patch, as is sooner or later the case when it is found on second year's wood.

The number of fruiting patches of alga becomes smaller as the season progresses from June onward, until by November it is usually difficult to find such a patch. At this season, however, in bad attacks, the bushes will often be found to be surrounded by a ring of dead twigs, and to have a certain number of dead twigs throughout, while a few of the stronger shoots in the centre of the bush have alone been able to throw off the blight, and consequently they are the only part of the plant which is growing vigorously. This appearance, coupled with a general aspect of hollowness about the bushes, due to the death of most of the smaller shoots, and the yellow unhealthy colour of most of the leaves, renders the recognition of a tea bush which has undergone an attack quite an easy matter after a little experience, even in the absence of any red patches on the stem whatever. (See Plate II.)

A bush attacked in the manner described is often, if not usually, still worse in the following season, and the ultimate result, if the disease be not checked, is first a continual reduction in its size at each pruning, and ultimately its death. The disease is thus a chronic one. The result in any particular season is the death of a smaller or larger number of young shoots chiefly on the margins of the bushes ; the continual repetition of this process leads ultimately to the death of the bushes themselves, though this stage is not usually reached until after quite a number of years. (See Plate III, Fig. 1.)

III.

DESCRIPTION AND LIFE HISTORY OF CEPHALEUROS VIRESCENS AS OCCURRING ON TEA LEAVES.

The alga occurs as orange yellow roughly circular patches on the upper surface of the tea leaf (see Plate III, Fig. 2); this rounded form of the thallus appears to be characteristic of the development on this host, and is rarely departed from; on other shrubs and trees the growth is irregular and frequently branched or stellate. The position of the thallus on the leaf does not appear to be regulated by any law beyond that which confines the original growth to the upper surface; patches of alga may be found indifferently on any part of the leaf from the midrib to the periphery; on the other hand, none have been observed on the petiole and only exceptionally on the under surface. The size of a patch varies up to about one centimetre in diameter. These patches, under close examination, are seen to be covered by a dense mass of delicate erect filaments, surmounted in most cases by sporangia, the '*haken-sporangia*' of Karsten. The orange-red colouring of these erect filaments is characteristic of this family. Under higher magnification the basal portion of the thallus is seen to be composed of cells arranged radially round the point of origin; a vertical section shows more than one such layer, the greatest thickness being in the centre

Sections including the host tissues (Plate IV) in normal cases show the algal thallus to be confined to the surface of the leaf, although sometimes partially embedded in the cuticle. The epidermal cells and the palisade parenchyma immediately below the alga are generally discoloured and dead, although this is not invariably the case. The palisade cells affected in this manner frequently show sub-division by transverse septa as the result of induced meristem formation. Marshall Ward was of opinion that this was possibly due to the action of the algal thallus in absorbing most of the light which would normally reach the sub-epidermal cells, and by this shading effect setting up excessive vegetative growth beyond the power of the neighbouring tissues to support. Such absorption would depend on the presence of the highly coloured hæmatochrom in the algal cells, but similar discolouration and death of the tissues of the host plant are found below immature algal patches which have not yet developed such highly coloured cell contents. On the other hand, many sections show apparently unaffected tissues below fully matured patches of alga. Whatever therefore be the cause of the formation of corky tissue underneath an algal patch, it can hardly be explained on Marshall Ward's supposition.

Vertical sections of the algal thallus and the tea leaf supporting it show varying stages of penetration by the alga. The germinated spore seems to possess the power of embedding itself firmly in the cuticle of the leaf, and as soon as active vegetative growth begins, the algal cells in many cases are found pushing their way beneath the cuticle as well as above it. The epidermal and sub-epidermal cells rapidly show the influence of the superincumbent algal patch, those nearest the latter are generally killed, and their brown tissues are characteristic features of such sections. The algal cells are sometimes difficult to distinguish from those of the host. Unlike the green cells figured by Cunningham (*l.c.*) in sections of the leaf of *Camellia japonica* showing penetration by the alga, those under the cuticle of the leaf of *Camellia thea,* so far as our examination of many specimens has shown, are almost invariably orange yellow, due to hæmatochrom, and are extremely rarely green. This is unlike what we have found in section of diseased stems, where the reverse is generally the case.

During the earlier months of the year, and in fact up to August, the penetration just described seems to be in normal seasons, the maximum occurring on the tea leaf in Assam. Later in the season, and earlier too if the atmosphere is kept moist by abundance of rain, however, many algal patches are found penetrating the lamina and producing a corresponding growth on the under surface of the leaf.* When this occurs, the algal patch on the upper leaf surface generally exhibits an annular formation. Both the fertile and infertile hairs are missing in the centre, which is occupied by the dead cells of the original thallus, generally including a few reproductive cells—the '*Kugel-sporangia*' of Karsten,—and also adventitious fungal hyphæ and spores. Many of the cells are filled with air, which gives them a lustrous white appearance apt to be mistaken at a casual glance for a lichenous growth. This white shiny condition also occurs on the outer edges of the circle and in many completely dried up algal patches.

On the lower leaf surface the algal cells which penetrate the lamina generally do so immediately below the centre of the ring above, and produce their reproductive filaments in this position (see Plate V). Further development on the under surface seems to depend on the vitality of the tissues of the host. On mature and consequently thick leaves sufficient nourishment is provided by the surviving parenchymatous tissue to allow of the extended growth of the alga, which may eventually attain the same dimensions on both surfaces of the leaf, although this does not occur simultaneously. Finally, the fertile hairs lose their terminal sporangia and cell contents, and the dead thallus remains as a crater-shaped depression surrounded by an elevated ring of black material, which microscopical sections show to consist of the intermingled dead cells of the parasite and its host.

The death of the alga is sometimes brought about more rapidly by its invasion by fungal hyphæ either growing on the neighbouring leaf surface or originating from spores entangled in the hairs of the thallus, forming an apparently compound organism which has been styled a lichen. This has been said also by Marshall Ward to be the result of the symbiosis of alga and fungus, but our observations have led to doubt profoundly the symbiotic character of the relationship. The modified character of the gonidial cells of the fungus to which he draws attention is not usually very much in evidence. We believe, in fact, that the fungus is from the first the enemy of the alga, and the death of the latter or at any rate the cessation of its vegetative growth undoubtedly takes place very shortly after the fungus invasion, and very much earlier than would otherwise be the case.

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* We have occasionally noticed this penetration also in the earlier part of the season (1907), especially when the amount of rain has been abnormal.

The position of leaves carrying algal patches on tea bushes does not seem to bear any relation either to light, shade, free access of air or rain-water, age of bush, nor situation of the latter with regard to other bushes or trees, nor does the healthiness of a bush render it even partially immune from leaf infection, except in so far as the greater number of actively growing *young* shoots and leaves on which the algal patches have not had time to come to maturity lends an appearance of freedom from the blight to the more vigorous individuals.

The importance of the form of *Cephaleuros virescens* occurring on the leaf from an economic point of view lies solely in the fact that it is one of the sources of infection of the stems by the destructive entophytic form on the stem. This fact, ascertained by actual experiment (*vide* infra page 18), would make it seem expedient, at first sight, to destroy all leaves carrying algal patches. Unfortunately, however, owing to the immense numbers of such leaves, this method of dealing with the blight is quite impracticable. In districts where the disease is serious, and indeed in some where it is not important as a stem blight, it may safely be said that on fifty per cent. of the bushes, infected leaves may be found at one time or another during the year, besides being very common in the jungle. Thus any attempt to exterminate the blight by destroying this source of infection is impracticable.

IV.

DESCRIPTION AND LIFE HISTORY OF CEPHALEUROS VIRESCENS AS OCCURRING ON THE TEA STEMS.

We have already sufficiently described the macroscopic appearances throughout the year occurring on a tea bush attacked with the cortical stem form of the alga under discussion. It remains for us to state what we have found of the means of dissemination, and of the actual effect produced on a tea stem which is attacked.

REPRODUCTIVE MECHANISM OF THE ALGA.

In order to understand the means by which dissemination of the disease may take place, it is necessary to study the reproductive mechanism of the alga. At a certain stage of development of the thallus, special cells, either forming the termination of a radial series (***kugel-sporangia***) or occurring at the tip of cellular hairs rising from the thallus (***haken-sporangia***) undergo changes as a consequence of which their contents become aggregated forming spherical masses. Previous to this change the cell contents consisted of minute granules varying in colour from green to dark orange, the latter colour predominating and being due to the presence of hæmatochrom. The aggregations are, however, invariably dark reddish brown, this colour being characteristic of the ripe sporangium. When fully matured, the sporangia of either kind are ruptured on access of water, and the contents escape as actively motile bi-ciliated zoospores, which swim rapidly about in the water, coming to rest after a few minutes in any new situation to which their own motion or that of the water may have carried them. Here further re-arrangement of the contents of the zoospores takes place, accompanied by active swarming motion and after periods of time, varying from a few minutes to several hours, these are set free by rupture of the enclosing membrane, the liberated spores being then free to germinate and so give rise to a new generation.

CHECKS ON THE SPREAD OF THE DISEASE.

Modifications of this series of events are of frequent occurrence and have a special interest in connection with the spread of the disease. Unripe immature sporangia in contact with water are ruptured very often in the same way as those which are fully mature. Numbers of such sporangia, both in the thallus itself and on the fertile hairs, the contents of which have not reached the stage of aggregation, are ruptured with dispersal of the contents. The same result frequently occurs with the terminal cells of infertile hairs, the contents of which exactly resemble those of immature sporangia, and when set free exhibit the same differentiation into minute granules and larger yellow oily drops.

Similarly, many of the zoospores set free from mature sporangia burst and liberate their contents before the further aggregation and maturation of the latter. This is frequently marked by the retention of the spores in an apparently gelatinous matrix which is extruded from the prematurely ruptured zoospore.

Now, if immature rupturing and liberation of the spores presupposes, as is highly probable, a corresponding failure in germination, we have here an important factor modifying the spread of the disease. Every shower of rain must find a certain percentage of immature sporangia which, although unripe, will lose their contents when wetted, thus lessening the number of zoospores which will ultimately germinate.

Although the diminution in the number of fertile zoospores brought about in this way may be inconsiderable, yet when we consider that every algal patch is liable to lose potential reproductive elements in a similar manner, it becomes obvious that the power of reproduction possessed by the alga will depend on its capacity to prevent by some means the premature dispersal of the contents of the sporangia. Now, one of the characteristics of the fructifying algal patch of *Cephaleuros virescens,* whether existing on the leaf or the stem, is the remarkable way in which it resists attempts to wet it. Thus, rain may be falling many hours without the patches being at all affected. The same is the case when an attempt is made to spray a plant on which red rust exists. After a very thorough treatment with a fine spray of Bordeaux mixture or Sulphate of Copper solution, many of the algal patches will be found to be quite dry, and not only that, but also to remain living afterwards while those which the spray succeeded in wetting invariably died.

The difficulty of wetting the '*haken-sporangia,*' however, varies very much with the stage of development which they have reached. When very immature, the wetting appears to be easy ; when the development has gone further, the difficulty becomes considerably greater ; when quite ripe an apical pore is produced on the sporangium, and the slightest contact of this pore with water causes sufficient wetting to lead to the expulsion of the zoospores, though, even then, the sporangium itself is only wetted with difficulty.

This difficulty of wetting has a distinct relation to the prevalence of the alga on a tea estate. The tea plant possesses leaves with a hard coriaceous surface, which does not become easily wetted, or, if wetted, does not retain much water. In such an estate there is evidently present an enormously greater possibility of the ripening of sporangia than would be the case with an area of plants not possessing leaves with such a hard surface. Hence, the sources of further infection are also enormously increased and the chance of breaking down the resistance of the living tissues augmented, simply owing to the multiplicity of attacks.

We have confirmed an observation made by Cunningham, that the effect of excessive moisture is, in a large measure, to prevent the formation and maturation of spores, the vegetative activity being correspondingly increased. Our own experiments in artificial cultures tell in the same direction.

In these experiments, gelatin was dissolved, in sufficient quantity to make the solution set on cooling, in diluted tea leaf juice, a small quantity of peptone being added, and 1 per cent. Citric Acid, and the whole spread in thin layers on the inner surface of test-tubes duly stoppered with cotton wool, and inoculated with mature sporangium heads, from a patch of alga on a tea leaf. Under these circumstances the alga was grown very successfully, the formation of the disk taking a perfectly normal course, but in the moist atmosphere of the culture medium and culture tube, no reproductive apparatus whatever was produced. A similar culture was made later on agar-agar, with the same result, but the culture was not so successful.

Still another cause exists preventing excessive reproduction. The time during which the '*haken-sporangia*' remain ripe and capable of producing zoospores is very limited, amounting as a rule to only a few days. After this they take on a darker colour, perfectly recognizable to the eye, and then cease to respond to the addition of water. Hence it is obvious that unless rain or dew or watering of some kind occurs during the short period when the sporangia are capable of reproduction, their capacity for disseminating the disease is lost.

In summary, it may, therefore, be said that the spread of the alga is kept in check by several means. The first is connected with the difficulty of wetting the algal patch and the sporangia and so not allowing the emergence of zoospores during the time these are in a suitable condition. This fact may, of course, as we have indicated, tell also in the opposite direction by preventing the rupture of immature sporangia. Again, excessive moisture leads to the production of few reproductive organs, or even of none, and so limits the spread of the disease during the height of the rainy season. And, thirdly, the length of time during which any particular sporangium head is capable of producing zoospores in contact with water is short, not exceeding a very few days.

METHODS OF SPREAD OF THE DISEASE.

It has been usually stated that algæ of the present type can only be originated by means of water-borne spores, and it has hence been imagined that the wind could have no share in their dissemination. With the former statement our results are in entire agreement, but nevertheless there remains no doubt that the wind is a very important factor in bringing the alga to the spot where the spores are to germinate.

The fact of the spread of this blight by water is proved completely by our experiments. Early in June 1904 certain bushes were set apart for inoculation experiments, and were kept under daily observation until September of the same year. In these attempts were made to transfer the disease (1) from leaf to leaf, (2) from leaf to stem, (3) from stem to stem, (4) from stem to leaf. In experiments (1) and (2) worsted threads were passed through algal patches on leaves bearing the blight, and led over the surface of healthy leaves (1), or stems (2), and water was allowed to drip at intervals from the threads which were kept moist by capillary attraction. This water-supply was kept up for three hours daily for the first month, after which it was discontinued. The bushes were kept under cover in a north verandah, rain only reaching them very occasionally. In Experiment (3), water was allowed, in a similar manner, to drip over a stem carrying the fertile hairs of the alga and to pass down the stem of a healthy plant; the algal hairs on the infected stem were kept in contact with the healthy stem, water passing between the two and subsequently down the stem of the uninfected bush. In Experiment (4) water was led from an infected stem and allowed to drip on to a series of healthy leaves. In Experiments (1) and (2) attempts were made to establish control areas by protecting parts of the leaf and stem from contact with the infected water stream. This was effected by painting lines of vaseline parallel to the normal direction of the flow of the water. In all, eight bushes were utilized for these experiments, two being under each class of treatment. All were just over two years old.

We may at once say that no infection resulted in Experiments (3) and (4), and at present we are unable to offer any reason for the failure, but from microscopic observation we do not believe it to be due to any lack of germinating capacity in the spores produced on the stem. Experiments (1) and (2) were, however, eminently successful in the sense that infection and normal growth resulted in each case. Five weeks after commencing the experiments, minute patches were observable on the previously healthy leaf surface in Experiment (1) ; eleven days later the most forward of these were removed for examination. The stage of development is shown in Fig. 1. Hæmatochrom was apparently absent or nearly so, nor were there at this stage any signs of reproductive organs. Six leaves were under treatment, and on four of these algal patches were found. On one of the four leaves, algal patches were developed within the control area, possibly by infection from outside sources.

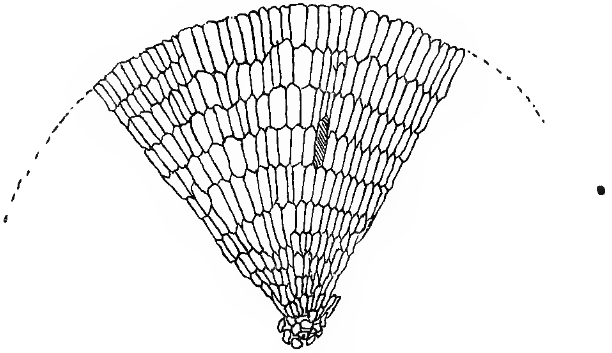

FIG. 1. PORTION OF ALGAL PATCH ON LEAF ELEVEN DAYS AFTER BECOMING VISIBLE ($\frac{1}{12}''$ oil immersion).

In Experiment (2), *i.e.*, infection from leaf to stem, the results were naturally more difficult to observe, and no patches with cellular hairs, the usual external evidence of the presence of the alga below the bark, were actually found, but its existence in the artificially infected stems was proved by examination of numerous sections of the latter. Most of the sections in which algal cells were found showed them growing in crevices of the bark and evidently pushing their way inwards in an attempt to reach the deeper seated tissues (Plate VI).

It is thus evident that the disease may be spread from leaf to leaf, and from leaf to stem by means of the zoospores carried in a gentle current of water. And a large amount of infection does probably take place in this manner. But the position of the alga on the tea bush, both on the leaves and stems, precludes the idea that it is the only means of spreading the disease. It is equally certain that the zoospores, as such, cannot be carried by the wind, as when they are once dried up, we have never been able to cause them to germinate again.

But on examination of an algal patch in fructification, the presence of a considerable number of cellular hairs with the sporangium heads obviously broken off will be noticed, and the ease with which this breaking off occurs is evidenced by the extreme difficulty we have had in getting sections showing the cellular hair and sporangium head together. Now, examination of the surfaces of numerous leaves, themselves free from algal patches, shows the presence of innumerable foreign bodies, mostly of fungal origin, but amongst these may occasionally be found the empty '*haken-sporangia,*' already detached from their original supporting filaments. A collection of extraordinary variety can be made on leaves *in situ* by lightly smearing the surface with vaseline.

Now, free sporangia have been observed to germinate on addition of water forty-eight hours after they have been separated from the thallus. The chain of evidence, therefore, seems practically complete. The sporangia are easily broken off from their supporting filaments : when thus broken off, they retain their germinating capacity for at least forty-eight hours; they are, when broken off, readily carried by the wind to new surfaces, and can there germinate and produce new colonies. We have ever been fortunate enough to observe completely mature sporangia separated from their parent thallus, and situated on the surface of a tea leaf, yet we have seen many in such situations whose cell contents were in an advanced state of aggregation.

It seems possible also that an already germinated sporangium may still be the means of carrying infection by wind in the following manner. In many cases the zoospores on escaping from the parent sporangium leave some of their numbers behind, which swim round and round, but seem unable to effect an exit. In a large number of our preparations, germinating spores of the second generation (*i.e.*, spores produced by aggregation of the contents of the original zoospore) are found confined in the otherwise empty sporangia. Thus a sporangium, already wetted, but still retaining some zoospores, and water, is quite capable of carrying infection to a new place. We have no evidence, however, that this is the case, other than that just cited.

We have then two methods by which sporangia may initiate infection on any fresh site. Water, the natural vehicle of the liberated zoospore, cannot raise the latter above its original elevation, but otherwise may possibly be the effective agent of spread. But wind carrying the sporangium as a whole, either ungerminated or already germinated and still containing zoospores and water, will take it to a position to which it could never attain by water carriage only.

CAUSES LEADING TO SUSCEPTIBILITY TO THE DISEASE.

It has been already stated that considered as a bark blight, *Cephaleuros virescens* is chiefly, though not exclusively, found on the young stems which grew in the year previous to that in which the fructifications appear. The infection must hence take place while the shoot is still young and either in the green herbaceous stage, or in that of tissue freshly covered with bark. Now, we have never found patches of alga on the young green shoot, which seems, in fact, to be unsuitable for its development. The same may be said of the outermost surface of the stem which has just formed a definite bark. Most of the sections of the stem in which algal patches were found to be present, showed them growing *in crevices of the bark.* This led to the conclusion that one of the principal causes which makes the tea plant particularly susceptible to stem attack by this alga is the irregular character of the surface of the young wood. The rough surface of this is eminently calculated to arrest the progress of spores carried down the bush by rain-water, or sporangia carried by wind, and subsequently to afford suitable sites for their germination. We have, however, not actually hitherto found sporangia in such positions. Plate

VII, Figs. 1 and 2, shows the rough irregular surface of the shoots during the first year of growth, as contrasted with the comparatively smooth bark formed later, and Plate VI, Fig. 1, a section of such wood, shows the lacunæ existing in the surface layer. It is in these lacunæ that the young algal patches are chiefly, if not entirely, found, and of course they afford the chance of the alga reaching the food-bearing layers of the shoot much more quickly and easily than if penetration through the outer lignified tissue had to take place.

In a healthy shoot such lacunæ are rapidly filled up by the natural processes of growth, which include not only the formation of a series of bark layers by the phellogen, but also the throwing off of the earlier formed external layers by exfoliation. This method of growth would, of necessity, militate against the penetration of the alga into the internal tissues, and its subsequent establishment as a parasite. Indeed, the inference seems inevitable that the probable immunity of a shoot and consequently of the tea bushes generally against penetrative infection by *Cephaleuros virescens* is intimately connected with the relative rate of growth of the superficial tissues of the bark and the germinated algal spores. It is most probable that other factors, of which we have not got clear evidence at present, come into play in enabling the tissues to resist the attacks of the parasite. We can, however, be sure that any causes which delay the development of the bark, and hence the removal of a young algal patch by exfoliation, will increase the susceptibility of the bush to the blight. In other words, a luxuriant, strongly growing shoot is much less likely to be attacked by the disease than a less luxuriant and less vigorous one.

This is one of the most important points in the practical study of the question. Bushes otherwise unhealthy are much more susceptible to 'Red Rust' attack than others, and, in general, it may be said that lack of vigour and want of condition in the tea bush is the primary cause of the stem form of the blight.

The disease, originated on a more or less unhealthy bush in the manner we have described, generally becomes apparent (see page 7) early in the year following the one during which infection took place. Bushes, the general unhealthiness of which may be indicated by the possession of weak and straggling shoots and leaves too light in colour or of a stunted character, are found, after the first showers of late April or early May, to bear on their stems the reddish patches which give the name of 'Red Rust' to this blight. These red patches, as has already been described, consist of the reproductive organs of the alga protruding through the bark in dense clusters (Fig. 2). These consist of delicate tubular septate filaments, most of which, but by no means all, carry sporangial cells at their extremities (*haken-sporangia*). The other form of sporangia (*kugel-sporangia*) embodied in the mass of the thallus and so common on the epiphyllous form of the blight on the leaf, is never found in the parasitic growth now under discussion.

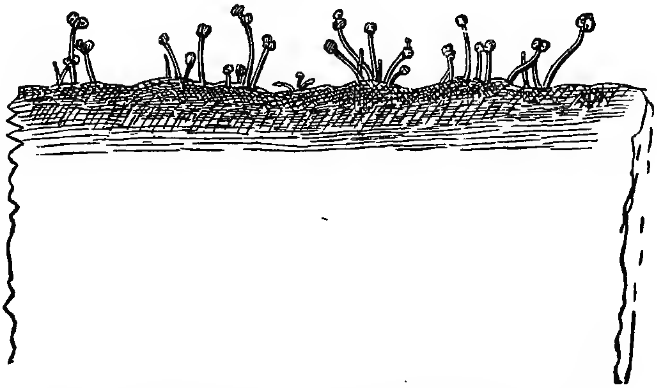

FIG. 2. APPEARANCE OF A PATCH OF *Cephaleuros* ON TEA STEM, IN THE FRUITING STAGE. (Enlarged and diagrammatic).

The portion of the alga concealed beneath the bark produces by its growth profound disruptive effects on the tissues of its host. Pushing its way among the cells below the bark, it sets up pressure, and hence irritation. The natural reaction of the shoot tissues to this irritation is the death of the cells in the neighbourhood of the latter. This forms a layer of dead cells intervening between the algal cell and the remaining tissues of the host (see Plate VI, Fig. 2). These may in some cases serve to cut off the supplies of moisture and nourishment from the alga, and so prevent the rest of the shoot being involved. The success of this method of resistance depends upon (1) the rate of growth of the algal cells and whether they can spread past the resistant layer, and (2) whether the shoot itself is sufficiently vigorous to survive the loss of tissue involved, for remoter parts of the stem may be cut off from nourishment if the vascular food-carrying tissues are extensively involved. At any rate the result is the removal of successive layers of bark. Where this fails in throwing off the parasite, the result is merely a fresh growth of the alga in a deeper stratum and a further loss of cortical tissue, the ultimate result being, of course, the death of the shoot.

In an unhealthy or non-vigorous bush the thin straggling shoots, which are more common near the periphery, are the worst nourished, and, as might be expected, are the first to be attacked. Similarly, in unpruned bushes a large number of the young stems are liable to be thin and ill-developed owing to their great distance from the source of food supply. At the Heeleaka Experimental Station lines of bushes were left unpruned to mark the boundaries of the various plots under treatment : more than fifty per cent. of these bushes during the season 1906 have shown the characteristic symptoms of red rust, although plots on each side of the dividing line have been practically free from it.

It will be seen that although unhealthiness and lack of luxuriance in the bushes is the principal cause of a serious attack by the disease, yet the life history of *Cephaleuros virescens* being as we have described, there are other contributory causes. Owing to the presence of a large amount of the leaf form on the tea itself and on plants in and round the blocks in question, there *may* be an immense increase in the chances of infection. This point, however, can best be considered under the next section (V).

The presence of the stem form of this parasite is frequently indicated (see page 7), by the chlorosis of the leaves (Plate VIII), on the shoots involved. This effect is most marked early in the season, but may be seen at any period of the year.

In the earliest stages of its growth in the stem an algal patch is, of course, of microscopic dimensions, but later it may spread up, down, and round the affected shoot, so that in aggravated cases the latter may be completely invested for several inches of its length. There is, in fact, no regularity of growth or limitation of size similar to that occurring with the epiphyllous form. When the shoot is invested with the patch of alga, it is invariably moribund, and frequently completely dead for some distance behind the point of infection. The further existence of the alga also terminates automatically only some time after the death of the host and some of its cells may then be found still retaining the green colouring matter which is such a curious characteristic of many of those living inside the tissues of its host.* It is quite possible that this continuance of life after the death of the host plant may indicate an absence of true parasitism, and that the alga only abstracts water from the host and interferes with the latter only by pressure. The facts at hand are, however, quite insufficient to decide the point.

Superficially the dead alga is represented by the dried up hairs, most of which have lost their terminal sporangia and coloured cell contents. Their air-filled cavities have a white appearance. The surface of the stem shows a slightly depressed scar due to loss of bark, surrounded by a blackened area consisting of the dead cells of the cortical tissues.

Vigorous shoots which have successfully resisted the algal invasion show similar scars, but of much smaller size (see Plate I). Their chlorosed leaves gradually regain their normal colour, and beyond the check on growth no further harm seems to be done.

THE ALGA ON THE COATS OF TEA SEED.

We have hitherto spoken of the epiphyllous form of *Cephaleuros virescens* occurring on the leaf and the entophytic form growing on the stem, but its extreme adaptability is shown by the intermediate forms which we have noticed and examined on the coats of tea seed.

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* The constant presence of chlorophyll in the deep seated cells of the parasitic form of *Cephaleuros virescens,* coupled with its absence, or at any rate its masking by hæmatochrom, in the cells in the surface growth on the leaves, is one of the curious observations made during the present study. We can suggest no explanation of the fact.

Here a great diversity of forms of the alga is found, ranging from the purely epiphytic to the decidedly entophytic condition, the former marked by the presence of *kugel-sporangia,* the latter by their absence. The various stages of the maturity of the seed show a corresponding series of developmental changes in the alga. In the earliest period of seed development, algal patches are found on the persisting flower carpels; these are purely epiphytic. Later on in the development of the seed, patches are found on the green seed coats, these also being at first epiphytic. As the seed ripens, the algal cells are found penetrating the superficial layers and taking on the characters of the cortical stem form, and as lignification of the tissues proceeds, a corresponding change takes place in the method of growth of the parasite, which is then found forcing its way among the cells along the lines of least resistance more or less parallel to the surface. Sections made at this stage may show a surface growth of the alga including both *haken-sporangia* and *kugel-sporangia,* whilst deeper down in the tissues are the layers of green coloured cells, characteristic of the stem form. We found the seed coats of tea particularly useful in providing specimens of the alga late in the season when the ordinary cortical form on the stem was difficult to obtain.

SUMMARY.

We may now summarize the principal points with regard to the life-history of the alga which we have established.

(1) The blight is propagated from existing algal patches to either the leaf or the stem of a bush. Such propagation may take place by two methods. Either the zoospores, after expulsion from a sporangium, may be carried direct by water to the position where they will germinate and grow, or the sporangium as a whole may be carried (after breaking off from its supporting filament) by the wind to the position, whether on leaf or stem, where it is

to grow. Here it becomes wetted, and thus ruptured, the zoospores are expelled, and these germinate and grow as before.

(2) The attack of young tea stems is intimately connected with their rough surface, for all young algal patches found occur in the crevices of this surface.

(3) The disastrous effect of the alga on the stem of the tea plant depends for its effective development on whether it can penetrate the tissues more rapidly than these are removed by exfoliation. In other words, if the shoot is growing faster than the alga, the latter is removed and no permanent infection takes place; if, on the other hand, the shoot is, through want of vitality, growing slowly, the alga is able to penetrate and destroy it. There is, hence, a direct connection between the spread of the blight and want of vitality in the tea plants attacked.

V.

PRACTICAL TREATMENT OF THE BLIGHT.

Our investigation of the life-history of *Cephaleuros virescens*, the results of which have just been detailed, shows evidently that, considered as a tea blight, it is capable of attack from two points of view. We can either endeavour to increase the luxuriance of the plant, or we can try to diminish the chance of infection. Other methods have been tried but with very unsatisfactory results, and experiments we have made with some of them may now be described.

The earliest method practised by planters after the general recognition of the serious character of the blight was the cutting out with a pruning knife of all the wood, carrying patches as soon as the 'red rust' appeared in April and May. It is obvious from our description of the life-history of the alga given above that such treatment was not likely to have any effect, but experiments were nevertheless made on these lines in Nowgong in 1904. The bushes selected for the purpose were eighteen in number, and were all badly rusted. It was found exceedingly difficult to cut out all the rusty stems in the first place. A note made at the time by one of us (C. M. H.) was as follows :—'The cutting out was not satisfactory to my mind, as although the women employed removed all the obviously rusted stems, I was able to discover about an equal amount with my lens still remaining on the bush, which would not be removed in ordinary garden practice.' In spite of this exceedingly careful cutting out of the disease, eight days later seven bushes had again distinct signs of disease upon them, as evidenced by chlorosed leaves, and this state of things continued throughout the season. At the end of the year there was not any additional new healthy growth as a result of the cutting, and the bushes were distinctly thinner. It was obvious, in fact, that no advantage had accrued from the treatment.

Another method which has been extensively employed is that of heavy-pruning or even collar-pruning (*i.e.*, cutting down to the ground) the tea. This has been done both in the regular pruning season and also in July. In both cases the method was not effective in ridding the bushes of the blight. Bushes cut down in Nowgong (Assam), in the cold weather of 1899-1900, were found seriously affected in 1901; in Sibsagar (Assam) bushes collar-pruned in 1902-03 were found with 'red rust' on them in 1904. Again, bushes cut down in July 1901 in the Tezpur district were by no means free two years later. In fact, our experience has been universally the same. Heavy-pruning of a rusty piece of tea, without other treatment, has invariably resulted in the production of rusty bushes again in the second year following the pruning.

Another suggestion was made by Watt in 1898 that a badly attacked plôt should be fired in February or in March. Time, experience, and further investigation of the habits of the alga has proved this method also to be quite futile against the disease and harmful to the tea which has been treated.

Almost equally futile have been the attempts to spray the bushes with fungicides at the time the blight is visible, that is to say, in the fruiting stage, either with Bordeaux mixture (sulphate of copper and lime) or sulphate of copper alone. It might, of course, have been a useful preventive of infection if nothing else but for the fact that it seems that the fruiting organs are only wetted with extreme difficulty, and with more difficulty by Bordeaux mixture than by sulphate of copper. Eighteen rusted bushes were sprayed with each of these very thoroughly on May 20th, 1904. On May 30th, six of those treated with Bordeaux mixture still showed living fruiting algal patches, and five of those treated with 2 per cent. solution of sulphate of copper. Examination of the patches themselves showed that about onethird of the width of the patches on each side (or two-thirds in all) had been killed by the spraying, but the middle was not affected at all. Such spraying is, therefore, not good enough even as a preventive of infection, and from our knowledge of the life-history it is quite obvious that it is useless to kill the alga in the last stage so far as the shoot on which it occurs is concerned, when it has already done all or nearly all the damage to the shoot that it can do.

These methods having failed, we come back to those depending on the increase in the luxuriance of the bushes and hence in their capacity to resist the disease. In other words, we have to find the causes of lack of luxuriance in each particular area, and to remove these. There is little need to do more here than enumerate the causes which in the Indian tea districts lead to lack of luxuriance in the bushes and hence indirectly to an attack of 'red rust.' The most important is probably the presence of defective soil and subsoil conditions, due to lack of drainage, to the formation of a hard pan in the soil, even merely to poverty of the soil, or to lack of adequate surface and deep cultivation. The remedy for these conditions is in each case sufficiently obvious. Again, some types of plant are more susceptible than others, a fact already well recognized in the affected districts. At the same time no variety of the tea plant known as yet seems to be altogether immune. In an existing area, where, as a rule, replanting of the land is out of the question for many reasons, the knowledge we now have can be of little use, but in planting out new tea the less susceptible types should certainly be employed. The 'Assam indigenous' variety as a whole is less resistant than the so-called 'Manipuri' or 'China' types of plant, or their hybrids with the 'Assam indigenous.' The factors determining this difference have not yet been ascertained, but they are, no doubt, closely connected with those which render the 'Assam indigenous' bushes more liable to be affected as they are, by adverse conditions of climate and soil.

The luxuriance of the bushes can also be largely affected by the system of pruning adopted, it being, of course, much safer from this point of view to obtain a smaller number of very strong well-grown shoots rather than a large number of more feebly grown ones. Hence clean pruning, that is to say, the removal of the small twiggy shoots throughout the bushes, is advisable, and also the cutting of each shoot left on the bush as short as possible consistent with leaving at least one bud or latent bud in the cut stem. The effect of denuding the bush of leaves by too close plucking in the earlier part of the season is another extremely frequent cause of lack of luxuriance and hence of 'red rust.' The avoidance of this fault is a necessity if the disease is to be checked.

Such are the principal underlying causes of lack of luxuriance in the plants, and hence the indirect causes of 'red rust' attack.

Before leaving this part of the subject, however, it is wise to refer to comparatively successful results which have followed the use of Bordeaux mixture as a spraying medium, not at the time when the red patches are visible on the stems, but during the previous pruning season (December, January, etc.) Contrary to what is the case later on, at this time the algal disks seem fairly absorbent, and there is little difficulty in wetting and hence killing them. As a result, in some cases the use of Bordeaux mixture under these conditions, applied as a spray immediately after pruning, has in a considerable number of cases, been markedly successful in reducing the amount of disease on a badly rusted lock. The Bordeaux mixture used was prepared by dissolving three pounds of sulphate of copper in twenty-three gallons of water in a wooden tub. In another vessel three pounds of lime were slaked in two gallons of water, and the milk of lime thus prepared added to the sulphate of copper solution. The treatment usually required 150 gallons of the mixture per acre.

There is one important means of attacking the blight that we have not yet dealt with, namely, the removal of possible sources of infection. We have already noted, however, that the alga occurs on the leaf of almost every hard leafed plant in Assam. As a stem blight it is by no means so common, but not by any means rare. Among the plants which are attacked on the stem are, curiously enough, two which are now frequently planted among tea for the purpose of increasing the luxuriance of the latter.

Albizzia stipulata—the *sau* tree of Assam—is, as is well known, now planted almost everywhere in the Indian tea districts and it is, when growing in tea gardens, seriously affected with 'red rust,' commonly attacked also. It exists on the old and on the young stems without distinction. In the former case the tree seems little, if at all, affected for a long time, but in the latter the young shoots die out in a manner quite similar to that in which tea is affected. Many warnings have been addressed to tea planters to avoid the possibility of spreading the disease by planting this tree in their gardens, but so far as our observation enable us to judge, it seems certain that the infection goes rather from the tea bush to the *Albizzia* trees, and as a matter of fact the tea bushes under *sau* trees affected with 'red rust' are themselves usually singularly free from the blight. In fact, the *Albizzia* seems distinctly less susceptible than the tea, and is rarely much affected except in very badly blighted tea gardens.

A second plant which has been recently used among the tea, particularly in Assam, is *Tephrosia candida*, the *boga-medeloa*—a leguminous bush growing about twelve to eighteen feet high, which is kept constantly pruned and the prunings buried at each round of hoeing. This seems particularly susceptible to 'red rust' under certain conditions, and may thus be a source of spreading the disease. These conditions relate to the manner of pruning. If the top of the bush is kept continually cut down, the alga establishes itself on the bark very virulently, but if only the side shoots are pruned and the centre one allowed to grow, there is usually little of the disease. The value of the plant is such that, even in face of a disease like 'red rust,' one would hesitate to recommend the abandonment of its use among the tea, and by the above simple alteration in the manner of its pruning, any evil effect it may have, will be very much minimized.

Beyond this any of our experiments to minimize red rust by minimizing the sources from which infection can be carried have one and all quite failed, and we have come to believe that the conditions are such in our tea districts that provided an unhealthy bush exists, from whatever cause, infection will find its way to it. Even new gardens put out in the middle of large grass plains where we do not know of the existence of the alga, contain the disease when the bushes have become unhealthy, a fact we have noticed in particular in Bishnath, Assam. This would lead to the supposition that the sporangia can be carried by the wind to very considerable distances and so largely render nugatory any attempt to reduce the sources of infection in and near the garden. At the same time, though there is at present no direct evidence of its advantage, we have urged in badly blighted gardens the removal and burial of leaves carrying the alga during the pruning season, in addition to those necessarily taken away during the pruning. Further than this it would not seem worth while, on present evidence, to go in attempting to reduce by a small proportion the amount of an all-pervading infection.

VI.—CONCLUSION.

We have described now, so far as we have been able to make it out, the life-history, method of growth, and method of dissemination of the alga *Cephaleuros virescens* as it occurs both on tea leaves and tea shoots, and given, in addition, the conclusions as to practical means of combating it which five years of experience have given us. There are still a great many points of difficulty in understanding this very obscure disease. In particular the sudden and constant appearance of the blight, whenever bushes become unhealthy from any cause whatever, throughout the whole of North-East India is a matter which we cannot at present understand.

The disease, under present circumstances, however, is by far the most serious of those to which the tea plant is liable in our districts. It will hence be kept under very close observation, and we hope that the present gaps in our knowledge of the subject will very shortly be filled.

BIBLIOGRAPHY.

D. D. Cunningham .. On *Mycoidea parasitica*, a new genus of parasitic algæ. Transactions of the Linnean Society, Vol. I. (Second series.) Botany, 1880, pp. 301-316.

D. D. Cunningham .. On an Entophytic alga occurring on the leaves of *Limmanthemum indicum*, with notes on a peculiarly parasitic variety of *Mycoidea*. Scientific Memoirs of Medical Officers of the Army in India, Part III, 1887, pp. 33-40.

D. D. Cunningham .. Bark Blight caused by *Cephaleuros virescens, Kunze*. Scientific Memoirs of Medical Officers of the Army in India, Part X, 1897, pp. 17-20.

H. Marshall Ward .. On the Structure, Development, and Life History of a Tropical Epiphyllous Lichen. Transactions of the Linnean Society, Vol. II. (Second series.) Botany, 1883, pp. 87-115.

G. Karsten .. Untersuchungen über die Familie der Chroolepiden. Annales du Jardin Botanique de Buitenzorg, Vol. X, 1881.

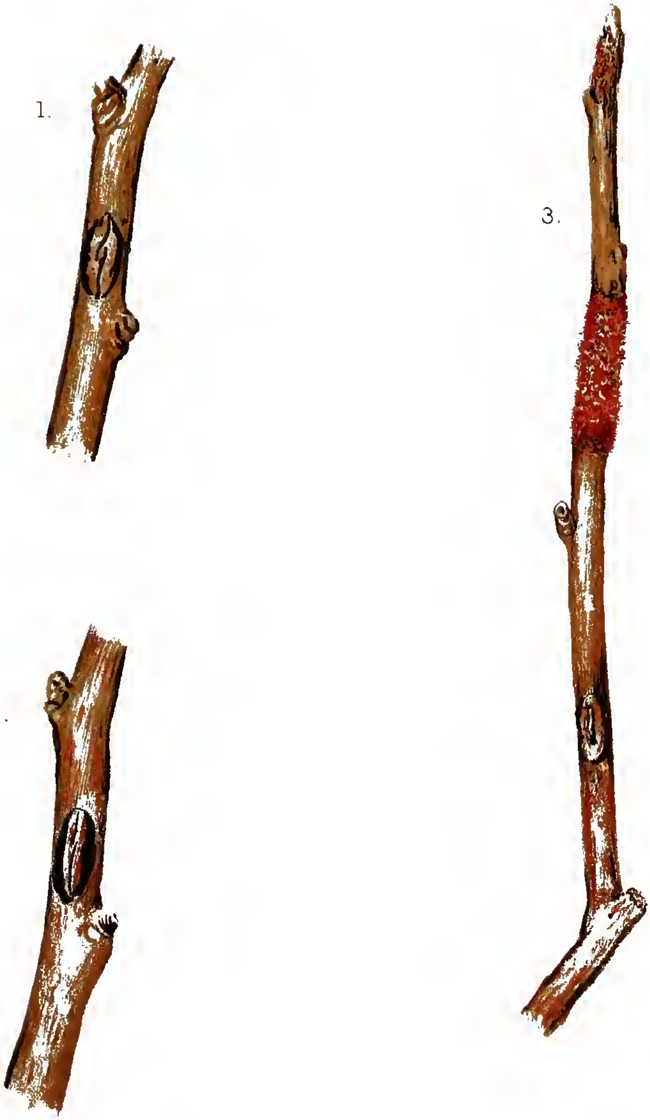
G. Watt .. The Pests and Blights of the Tea Plant. Calcutta, 1898, pp. 443-459.

G. Watt and H. H. Mann. The Pests and Blights of the Tea Plant (Second edition). Calcutta, 1903, pp. 396-408.

H. H. Mann .. Red Rust: a serious Blight of the Tea Plant. Calcutta, 1901.

H. H. Mann and C. M. Hutchinson. Red Rust: a serious Blight of the Tea Plant (2nd edition). Calcutta, 1904.

Plate I.



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CEPHALEUROS VIRESCENS ON TEA SHOOTS.
1 & 2. Show healed up scars of former algal patches.
3. Shows two living fructifying algal patches and one healed up scar.

PLATE II.

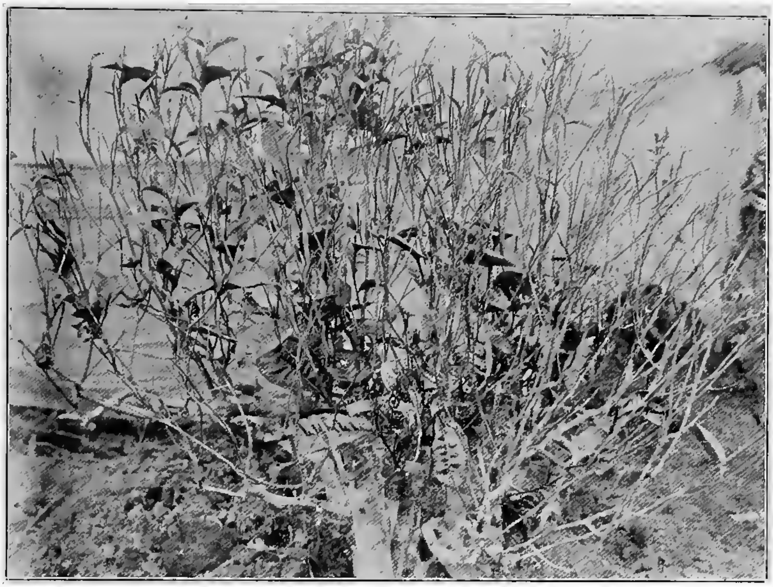


Fig. 1.—Tea Bush seriously attacked by Cephaleuros Virescens. (June).

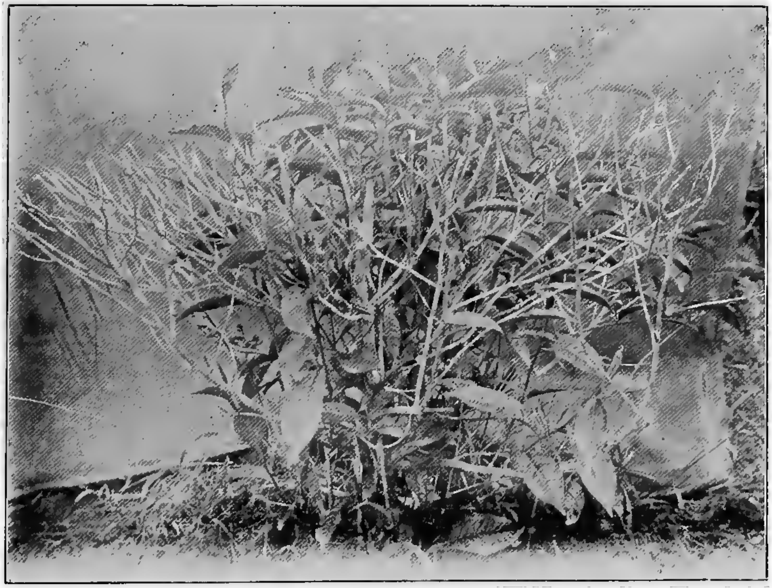


Fig. 2.—Tea Bush seriously attacked by Cephaleuros Virescens. (June).

PLATE III.

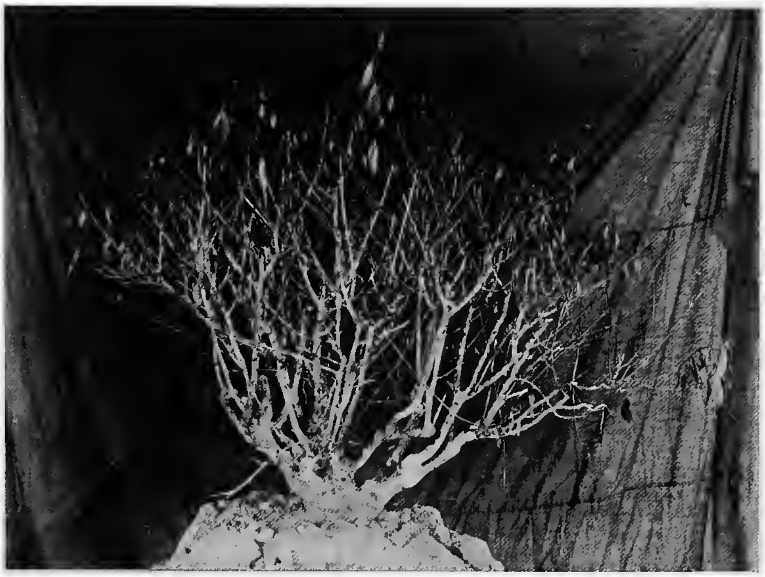


FIG. 1.—TEA BUSH DYING THROUGH RED RUST ATTACK LONG CONTINUED.

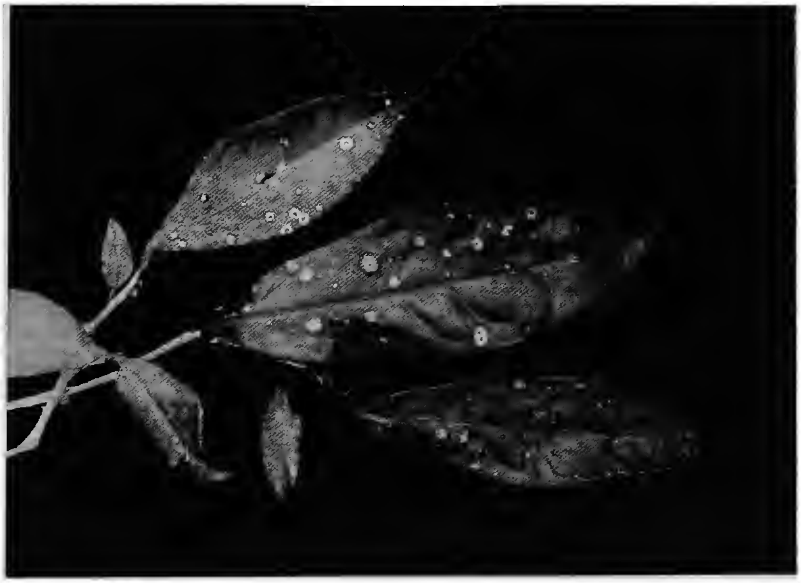
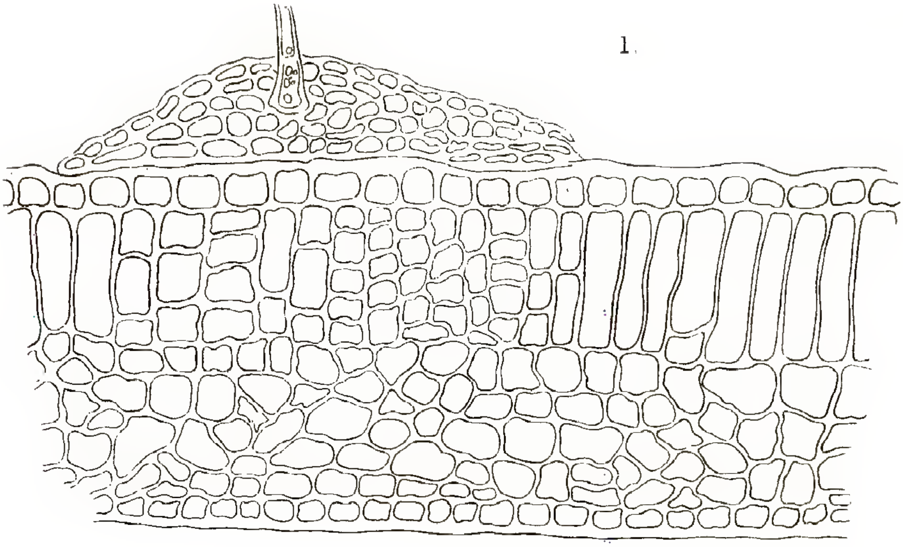


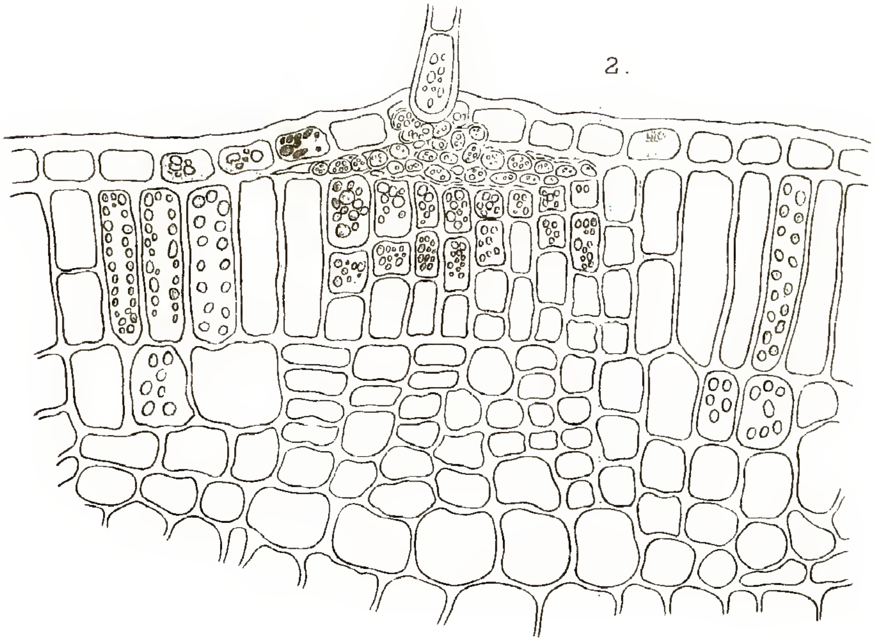
FIG. 2.—PATCHES OF CEPHALEUROS VIRESCENS ON TEA LEAVES.

Plate IV.

1.



2.



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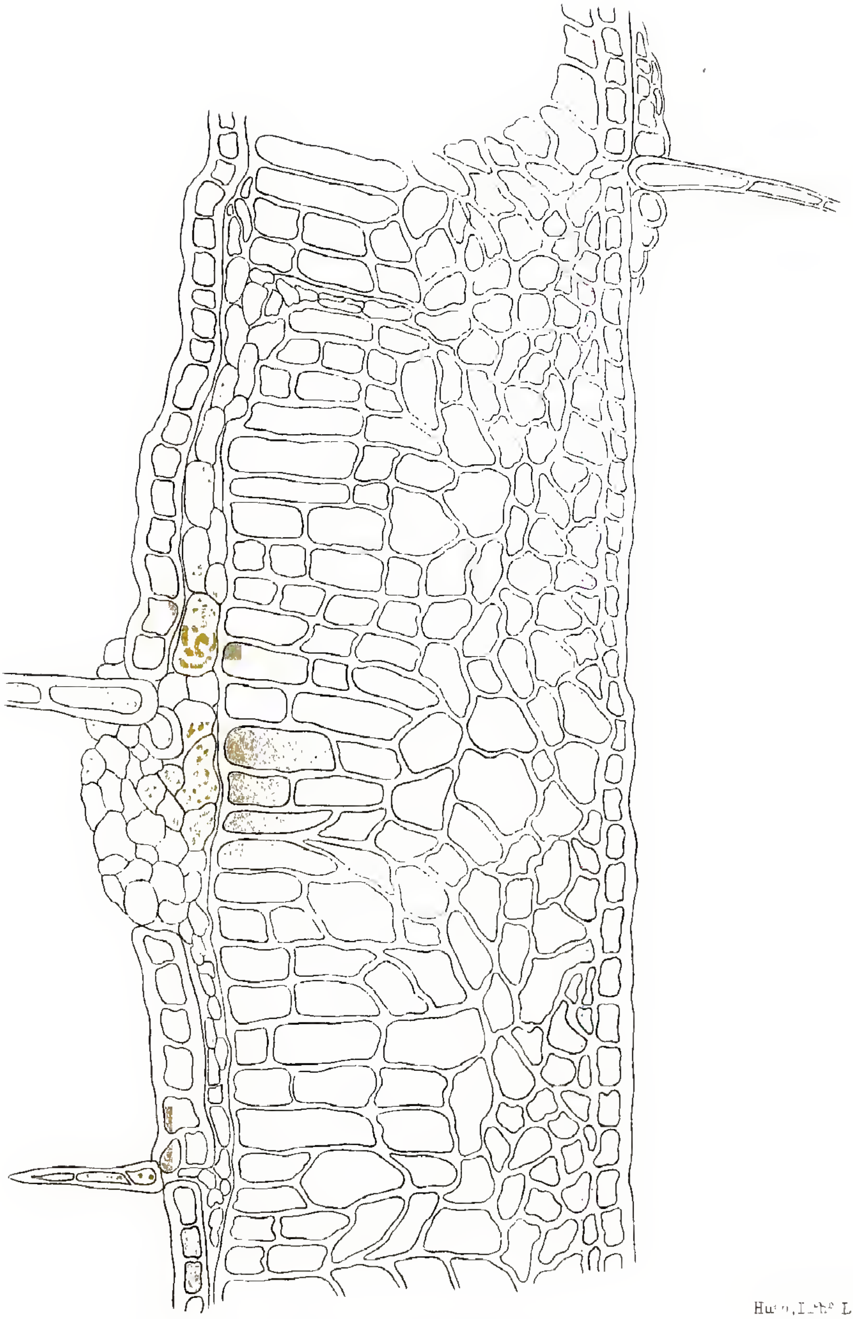
CEPHALEUROS VIRESCENS ON TEA LEAF.

Sections through algal patch, showing (Fig. 1) a purely superficial growth, and (Fig.2) a growth embedded in the cuticle.

Plate V.



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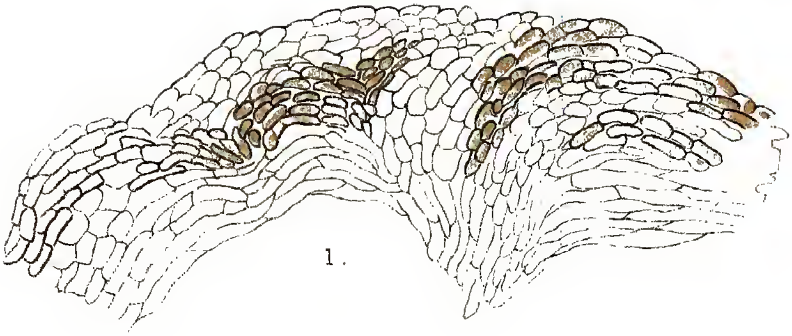
CEPHALEUROS VIRESCENS ON TEA LEAF

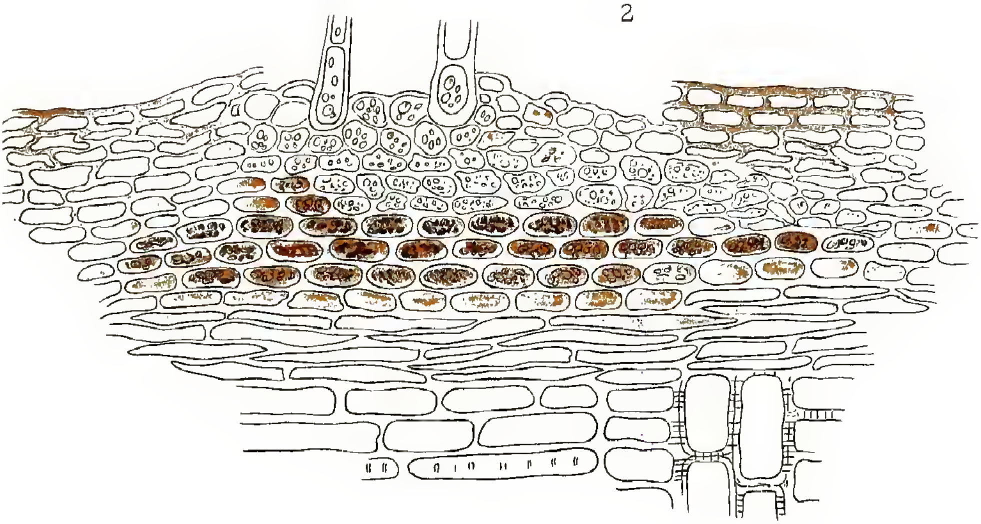
Section through algal patch, showing complete penetration of the leaf.

Plate VI.



1.

2



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CEPHALEUROS VIRESCENS ON TEA STEMS.

1. Cross-Section of portion of young tea stem showing crevices by which the blight gains admittance. Brown liquified tissue. Green = alga.

2. Cross Section of portion of stem attacked by "Red Rust". Green = algal cells. Dark Brown = dead cells beneath algal growth.

PLATE VII.

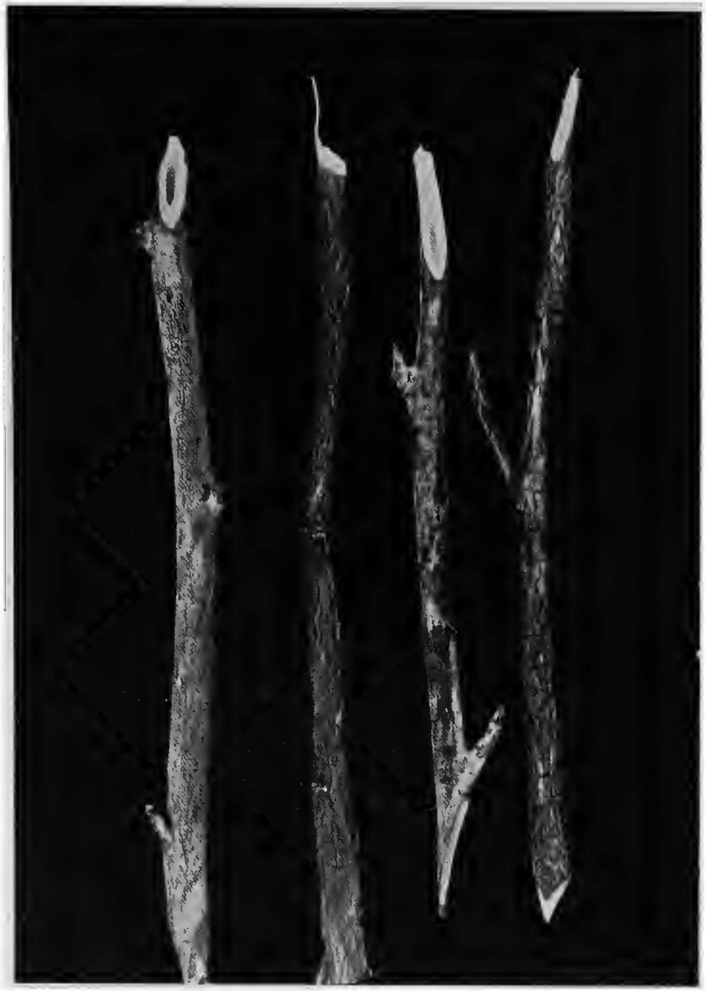


Fig. 1. The irregular surface of the bark on young tea shoots. 2 and 4 are quite young shoots, 1 and 3 are more than a year old and have smoother bark.

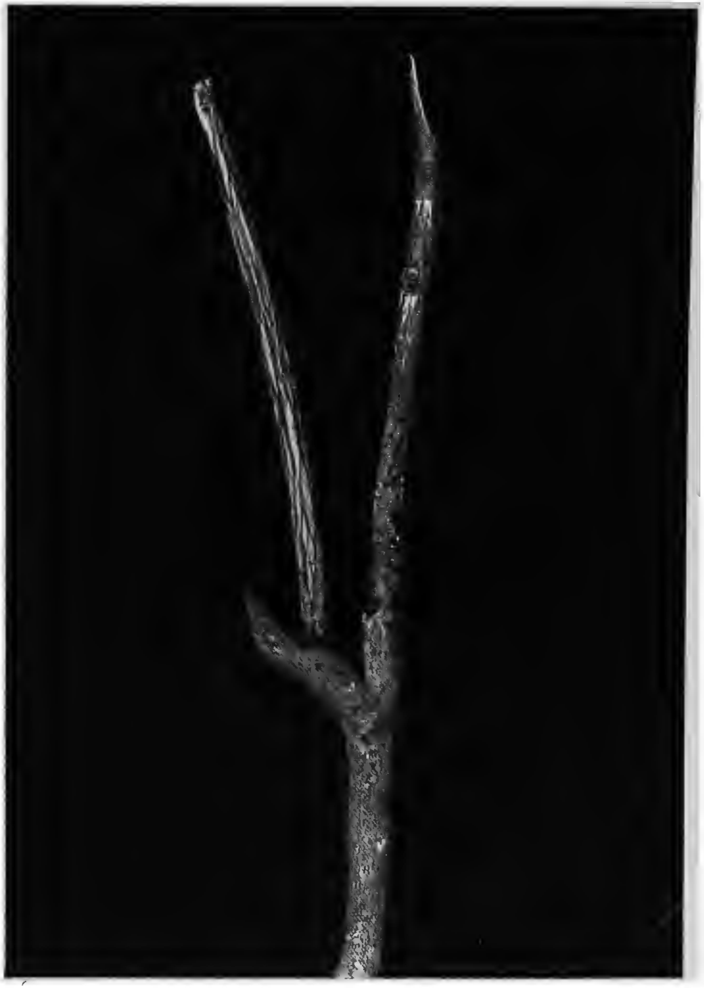
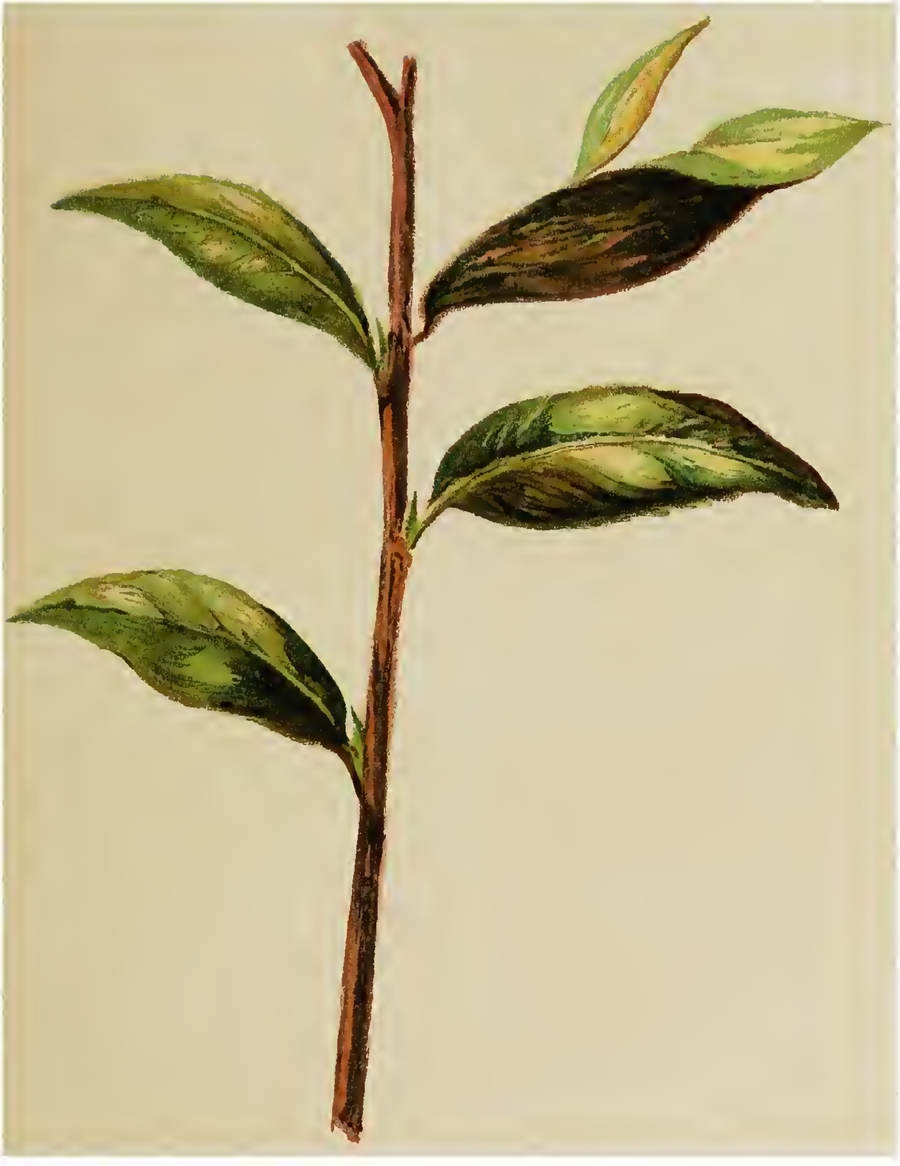


Fig 2. The irregular surface of the bark on young tea shoots; the left hand shoot is quite young, the right hand shoot is over one year old.



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CEPHALEUROS VIRESCENS ON TEA SHOOTS.
Shoot carrying Red Rust with chlorosed leaves.

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